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AUTHOR Clarke, H. Harrison, Ed.
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ABSTRACT

This report, one of a series on research into specific physical activities and their efficacy in improving and maintaining physical fitness, examines sport participation and the potential it has for developing muscular strength, muscular endurance, and circulatory-respiratory endurance. The activities consist primarily of the following twelve sports: archery, badminton, basketball, bowling, handball, field hockey, ice hockey, paddleball, skiing, soccer, tennis, and volleyball. Documentation is presented rating these sports into groups of "vigorous" and "mild" activities. The contribution that participation in milder activities makes to the improvement of physical fitness is examined. Three comprehensive evaluations of contributions from participation in various activities to the improvement of physical fitness components are made, one evaluation drawn from the opinions of physicians and two from exercise systems proposed in research. A summary analysis of the physical fitness benefits realized from participation in each of the twelve sports is presented. Three basic principles to which participants in physical activity should pay heed are defined: (a) exercise should be adapted to the individual's exercise tolerance; (b) reasonable "overloading" should be applied to induce higher levels of performance; and (c) the exercise should be progressive. (MJB)

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SPORTS POTENTIALS FOR PHYSICAL FITNESS

Three earlier issues of the *Physical Fitness Research Digest* were devoted to summarizing research literature on the use of specific activities in the improvement and maintenance of physical fitness components, especially muscular strength, muscular endurance, and circulatory-respiratory endurance. These *Digest* issues were: January 1977, "Jogging"; July 1977, "Swimming and Bicycling"; and October 1977, "Rope Skipping-Dancing-Walking and Golf-Pack Carrying." This *Digest*, fourth in the series, presents the potentials of sports participation in the improvement of the various physical fitness components.

Problems Encountered in the Application of Sports & Physical Fitness Studies

From the standpoint of desirable scientific practices, investigators strive to control or equalize the vital elements involved in their experiments. Better controls can be applied to some activities than to others in studies involving the improvement of physical fitness components; this situation has been considered in other relevant *Digests*. Activities which permit maximal control are weightlifting and the walking-jogging-running continuum on a motor-driven treadmill. In weight training, the amount of weight lifted and the number of repetitions can be definite; the same is true for treadmill performances, with speed, elevation, and time prescribed. The bicycle ergometer has similar advantages, except the subject must voluntarily maintain a prescribed number of revolutions per minute; rope skipping presents a comparable situation. Such controls have been much more difficult to apply in swimming studies, although the recent use of specially devised flumes may change this situation. In sports, however, other problems exist in determining dosage. Parenthetically, it may be added, all studies involving volitional exhaustive efforts, the motivation of the subjects, and their willingness to go all out, defy precise control.

When a person runs two miles in 20 minutes, the effort is definite and objective; it represents a defined accomplishment. If the run is on a motor-driven treadmill, the pace is even throughout, the running surface is smooth, and the elevation is designated from flat to inclines of varying degrees. By contrast, if the person plays basketball for 20 minutes, the intensity of participation is not known and will vary from individual to individual and from time to time depending in large degree not only on the participant's level of skill but on the opponent's level as well. Close, hard-fought games, when maximal activity takes place, are usually found when opposing teams or individuals are of comparable ability. Contests between unequally matched teams are somewhat lackadaisical in nature. The same is true for such court sports as handball and tennis, but they have the additional

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variable of whether singles or doubles matches are being played. Thus, studies of the contributions of participation in sports in the improvement of physical fitness components can be determined for a given situation, but the degree of effort is not known. The effort is hard to quantify.

Additional problems arise in several of the studies reported in this account, as evaluations were made during physical education class participation in the sport or sports under investigation. Class activity usually involves some competitive play, but also includes time for explanations, instruction and practice of fundamentals of the sport, and drills. The level of intensity and the results obtained under such circumstances are shown, which has value inasmuch as these studies demonstrate that class participation in a sport can be helpful in improving physical fitness components, but not necessarily the maximal benefit that can be realized from the sport under more regulated conditions.

Shephard (38, p. 474) has indicated still other complicating factors which suggest caution in comparing the results of studies conducted in a given sport after a lapse of years. The passage of time may have been accompanied by alterations in rules, development of better but heavier protective equipment, and introduction of new techniques of play. If present, these changes challenge the current validity of previously reported fitness results.

The development of telemetry for recording electrocardiograms electronically has been a boon in the study of some cardiovascular effects of sports participation. A continuous record can be made, if desired, before, throughout, and after engagement in a sport. Attached to the body are only small electronic sending units; the person is unencumbered by wires and other attachments. As is well known, telemetry was used for transmitting to earth the status of various body functions of astronauts in outer space and on the moon.

The amount of research on the improvement of physical fitness components through participation in sports is very sparse in some sports; the smallest number reported here are 2-3 for ice hockey, paddleball, and soccer, and the largest number is 19 for basketball. Further, some studies are not confined to a single sport; rather, comparisons are made between two or more sports. Some studies are not confined to sports but include other conditioning activities as well; and, in some studies, sports participation is confined to physical education class situations. As a consequence, this "scattering" of available studies made for a somewhat awkward organizational arrangement of this account. While other sports and activities appear in the studies reported, 12 sports have been singled out for primary foci, as follows:

Archery	Hockey, Ice
Badminton	Paddleball
Basketball	Skiing
Bowling	Soccer
Handball	Tennis
Hockey, Field	Volleyball

Each of these sports will be designated in this report as a *focus sport*.

Three Comprehensive Evaluations

Three comprehensive evaluations involving several sports each have been made. One of these is a brief survey of medical opinions and the other two are contained in exercise systems. The evaluations indicate the contributions of sports and other activities to the improvement of physical fitness components.

Some Physicians' Opinions

A panel of seven medical experts were employed by the President's Council on Physical Fitness and Sports (9) to subjectively assess the special contributions to physical well-being of 14 popular but diverse forms of exercise. Nine elements were evaluated for each activity, as follows: cardiorespiratory endurance, muscular endurance, muscular strength, flexibility, balance, weight control, muscle definition, digestion, and sleep. Ratings were on a scale of 0-3; thus, a rating of 21 indicates maximum benefit (a score of 3 by all seven panelists). Ratings were made on the basis of regular activity at least four times a week for 30 minutes or more in a given activity.

Overall ratings (sum of ratings on the nine elements) from greatest to least contributions to fitness were as follows: 148, jogging; 142, bicycling; 140, swimming, skating, and handball/squash; 139, Nordic skiing; 138, Alpine skiing and basketball; 128, tennis; 126, calisthenics; 102, walking; 66, golf with riding cart; 64, softball; and 51, bowling. Singling out the sports and adding jogging for comparison the following tabulation presents their ratings by elements.

Ratings by Medical Panelists

Elements	Basketball	Bowling	Handball Squash	Skiing Alpine*	Skiing Nordic*	Tennis	Jogging
C R Endurance	19	5	19	16	19	16	21
Muscular Endurance	17	5	18	18	19	16	20
Muscular Strength	15	5	15	15	15	14	17
Flexibility	13	7	16	14	14	14	9
Balance	16	6	17	21	16	16	17
Weight Control	19	5	19	15	17	16	21
Muscle Definition	13	5	11	14	12	13	14
Digestion	10	7	13	9	12	12	13
Sleep	12	6	12	12	15	11	16

**Alpine skiing: downhill and slalom. Nordic skiing: cross-country and jumping.*

Coopers' Aerobic Point Systems

Cooper for men (10) and Cooper and Cooper for women (11) have proposed point systems for the values of various activities for conditioning the cardiovascular system, called *aerobics*. The general plan is for the individual to accumulate 30 points per week from a selection of activities; each activity has point values for various amounts of participation. The aerobic values were derived from laboratory measurements of the oxygen costs of the exercises, as well as data obtained from field tests. The aerobic point system is given in detail in the appendix of each book; in assigning points, participation in an activity must be continuous for the speed and/or time given. Some sports are included in the aerobic system. For males, the following illustrations show their relative values (expressed here for comparable times):

1 point: each 15 minutes of volleyball (1 1/3 point equivalent for 20 minutes).

1½ points: each 20 minutes of singles play in badminton and tennis.

3 points: each 20 minutes of basketball, handball, hockey, and soccer.

6 points: each 20 minutes of cross-country skiing (9 points for 30 minutes).

The same point values are applied to female participants, although only the sports of badminton, skiing, tennis, and volleyball are included among their tables. By contrast, 3 points are awarded for jogging one mile between 11:50 and 10 minutes and swimming 350 yards between 8:44 and 5:50 minutes.

Fitness Finders

In *Activetics*, Kuntzleman (29) has presented the energy cost of a great many physical activities: various occupations, recreational and fitness activities, and sports for each of 18 categories, or Activetics numbers. Activetics numbers are based on the height and weight of the individual. Kuntzleman (30) also developed a slide rule as a caloric counter, known as "Fitness Finders." To use the counter, a slide is moved to set an arrow at the user's weight. The figures showing in a slot are the number of calories burned per hour for participation in nearly 100 physical activities. Using the slide, the calories burned per hour for sports mentioned in this *Digest* by a 90-pound person are:

Sport		Calories Per Hour
Archery		565
Badminton, Handball, Volleyball:	moderate	625
	vigorous	1071
Basketball:	moderate	773
	vigorous	1085
Bowling:	nonstop	731
Skiing:	downhill	1060
	level at 5 mph	1285
Soccer		981
Tennis:	moderate	754
	vigorous	1071

Single Focus Sports

In this section, studies conducted on the contributions of single focus sports and the improvement of physical fitness components are presented, i.e., only one of the 12 focus sports is involved in a study. However, other activities, such as jogging, swimming, golf, etc., are included in some of these studies. The sequence of focus sports is arranged alphabetically. The only focus sport not included is bowling, inasmuch as studies related to this sport include other focus sports as well.

Archery

Gibbs (21) studied the effects of participation in archery on the development of arm and shoulder girdle strength. The subjects were 62 college women who participated in an 8-week instruction course in beginning archery. The strength tests administered at the beginning and end of the course were: pull and push strength using a hand dynamometer with handle attachments for this purpose; and two cable-tension tests designed to measure pulling strength at beginning-draw and full-draw positions. Archery skill performance was evaluated by the Columbia Round score and corresponding hits as well as the class score as accumulated during the total instructional period. The three pulling strength tests improved significantly with t ratios between 6.22 and 7.83 for the differences between initial and final means. Pushing strength did not change appreciably. Low but significant correlations were reported between pulling strength and archery performance scores (around .25).

Badminton

The intensity of badminton participation, as reflected by heart rates, was evaluated by Huntington (27) during a 6-week course in this sport. The subjects were three college men, all 19 years of age. Heart rates were monitored by telemetry five times for full class periods during a 6-week badminton course. The results showed that a very small amount of class time was strenuous enough to elicit heart rates of 148 beats per minute or more. Whenever the subjects' heart rates did reach this level, it either was during vigorous badminton play or was associated with testing badminton ability. The high heart rates found during testing circumstances was assumed by the investigator to be due to psychological factors present in testing, as only moderate activity was involved in such testing. On rare occasions during strenuous badminton play the heart rate of individual subjects reached 180 beats per minute for short periods of one to three minutes.

Changes in muscular endurance tests during one semester of class participation in four physical education activities were assessed by Fordham (18). The four activities were selected, as follows: light activity, badminton; intermediate activity, tumbling stunts and apparatus stunts; and heavy activity, basic conditioning. The muscular endurance tests were chinning, floor pushups, sitting tucks, and hops. In terms of muscular endurance, the badminton participants had the lowest gain; the amount was 3.07 standard scores.

Basketball

Several approaches have been made by various investigators in assessing the values of basketball participation in the improvement of physical fitness components. These include oxygen consumption, heart rate, blood lactate concentration, body composition, and muscular strength.

Oxygen Consumption. Sprynarova (42) investigated the effects of four physical education activities upon the maximum oxygen consumption of boys. The four activities and the number of boys in each were: athletics, 22; basketball, 31; nonsporting, 23; and various sports, 38. The subjects were tested three successive years at the ages of 11, 12, and 13. No significant change occurred in maximum oxygen consumption per kilogram of body weight for the basketball group.

Oxygen Consumption and Heart Rate. With six members of the University of Wisconsin, La Crosse, basketball team, Hetzel (24) studied the aerobic and anaerobic energy requirements of players involved in full-court style basketball. Heart rate was measured by telemetry while playing in an actual game; oxygen uptake was obtained by a treadmill test. It was found that, given the same heart rates, forwards use more oxygen than guards; the anaerobic energy system is used more exclusively by the forwards than by the guards; and 83% of all energy used to play this particular style of basketball is aerobic in nature.

Two women on a women's intercollegiate basketball team were tested by Bode (5) using two home games for obtaining heart rate responses by telemetry; the subjects were also tested for maximum and submaximum oxygen uptake while treadmill running. During games, the respective subjects had peak heart rates of 196 and 212 beats per minute. Estimated caloric expenditures for an entire game were 642°C for one subject and 502°C for the other.

Blood Lactate. Cranford (12) measured and/or predicted blood lactate concentration, heart rate, VO_2 pulmonary ventilation, and workload as female college athletes performed various types and intensities of work. Blood lactate production was found to be a better method of assessing the strenuousness of physical activity than was heart rate. On the basis of lactate production, women's intercollegiate basketball involves moderate to heavy work.

Muscular Strength. In three basketball classes for sophomore high school girls, Allen (1) formed three groups of approximately 30 girls each. An experimental period of five days a week for five weeks was established. One group skipped rope and a second group bounced on the trampoline, each continuously for one minute; the third group continued with basketball practice. The effect on strength was determined by use of six cable-tension strength tests. The results of only two of these tests, hip flexion and extension, are reported here, since they were the only ones in which reliability coefficients of .86 and above were obtained by the investigator. The basketball group remained approximately the same during this period. The only significant improvement was in hip flexion strength by the trampoline group; this group was superior to the rope skipping and basketball subjects on this test.

Riley (37) applied five physical fitness measures to 21 male college basketball players before and after a season of competitive play. The tests utilized were resting pulse rate, grip strength, leg strength, Harvard Step Test, and skinfold thickness. The only significant improvement was in leg strength.

Strength and Endurance. Parchman (35) compared the leg strength and C-R endurance of college women during a semester's class participation in basketball and swimming. Leg strength was tested with a dynamometer; endurance was determined from the time a bicycle ergometer ride could be continued at a set number of revolutions per minute and constant load. The basketball participants showed a significant increase in leg strength but not on the endurance test. The swimmers did not improve significantly on either test.

Body Composition. Cohen and Harry (8) studied the extent to which the body composition of college women was altered through participation in basketball, swimming, and physical conditioning classes. Twenty subjects were assigned to each activity and to a control group. Measurement of potassium-40 and selected anthropometric measures were used to determine body composition. The results were as follows: (a) All three groups significantly changed their body composition during the course of participation in the activity classes. (b) For the basketball and swimming participants, body fat decreased and some girth measures increased significantly; weight remained unchanged. (c) For the conditioning class, no significant changes occurred for the measures utilized in the study.

Body Composition and Strength. Changes in body composition and strength of 19 women from the Ohio State University women's midwest regional championship basketball team were reported by Oyster (34). The same tests were administered before and after the competitive season. The body composition measures were four skinfolds, body density, and fat percentage, and nine girths throughout the body. The Oregon Cable-Tension Strength Composite for college women, consisting of ankle plantar flexion, hip flexion, and shoulder flexion, provided the strength evaluation. The results showed a 33 percent gain in Strength Composite; according to the norms, the basketball athletes achieved a T score of 60 (approximately the 84th percentile) at the close of the season. Body composition changes included decreases in all but one skinfold (over iliac west) and all girths of the arm, chest, and calf (accounted for from fat reduction rather than decreases in muscle size). Weight remained the same. Lower extremity measures especially showed significant changes.

Motor Ability Items. Bennett (4) contrasted motor ability scores of 75 college women randomly assigned to classes in modern dance, folk dance, swimming, and basketball at the end of 16 weeks of class participation; pretests were not given. Eleven tests were administered to measure agility, coordination, grip strength, abdominal strength, flexibility, speed, leg strength, leg power, arm and shoulder girdle strength, balance, endurance, and general motor ability (Scott's test). The basketball participants had significantly higher means than the folk dancers on the Burpee squat-thrust test (agility), right grip strength, and trunk-hip flexibility. They had a lower mean than the swimmers on the 30-second situp test (abdominal endurance). Without tests at the start of the study, it is not known how much influence initial differences between the classes may have contributed to the final differences.

Handball

Bryant (6) showed significant gains in nine adult men from handball participation as compared to a control group in the following physical fitness related tests: heartometer brachial pulse wave measures, the Schneider cardiovascular test, and expanded chest girth minus abdominal girth. Pulse rate, respiratory tests, dynamometric strength, and agility did not change significantly.

Hockey, Field

As the game was played in 1932, the distance traveled and the rate of speed of movement of college women field hockey players was determined by Espenschade (15). The women serving as subjects were from elementary field hockey classes, from class teams at the University of California at Berkeley, and from club teams of the Northern California Field Hockey Association. The greatest total distances traveled in a

60-minute game were: 2.7 miles by center forwards, 2.9 miles by right fullbacks, and 3.1 miles by right halfbacks. The distances covered per 3-minute period varied with position and with skill of players. Among defense players, the right half traveled the greatest distance, followed in order by left half, left full, and right full. The "good" center forwards traveled a shorter distance than did the "fair" and "poor" center forwards; the same situation was reported for "good," "fair," and "poor" right fullbacks. During the playing period, continual fluctuations were noted in distance covered and in periods of inactivity.

Hockey, Ice

Telford (43) assessed the cardiorespiratory capacity of fifteen 10-year-old boys engaged in ice hockey competition. The boys had been participating in organized ice hockey for 4.4 years, 2.9 years of which had been in competitive leagues. In addition, the results obtained were compared with national (Canada) and international age-matched data, as well as with university hockey players. When compared with non-athletic boys of similar age, the maximal oxygen uptake of the subjects was significantly higher; in comparison with other data on Canadian age-matched boys, their values were 33 percent higher. The results of physical work capacity determinations at a heart rate of 170 beats per minute ranked the 10-year-old hockey players in the top 20 percent of Canadian boys of the same age. While adult hockey players had more efficient oxygen transport systems than did the 10-year-old players, the difference measured during heavy work was not significant.

Paddleball

Donatelli (13) evaluated the physiological demands of participation in paddleball, running, and calisthenics for 10 men, 42 to 58 years of age, by peak and mean exercise heart rates and by estimation of energy expenditure. The subjects were considered to have average playing ability in paddleball and were participating in running and calisthenics at the time of the study. Each subject's heart rate was telemetered continuously for 15 minutes of participation in each activity. The oxygen consumption-heart relationship was determined on several occasions at various submaximal levels of work on a treadmill. The heart rate results were as follows:

	Mean Heart Rates		
	Paddleball	Calisthenics	Running
Peak Heart Rate	159	154	174
Exercising Heart Rate	143	127	154

The results demonstrated that mean estimated VO_2 (ml/kg/min) and exercising heart rates for running were significantly higher than for paddleball and calisthenics, and paddleball was significantly more strenuous than calisthenics on these circulatory tests.

Skiing

During a winter carnival at Middleburg College, Hanson and Tabakin (23) telemetered the electrocardiographic responses of four members of the college ski team during the cross-country, downhill, and jumping events. These skiers had been in training for approximately three months and were active in other sports during the

school year. The range of maximum heartbeats per minute of the contestants during the events were: 187-200, cross-country; 158-167, downhill; and 115-166, ski jump. The anticipatory (before events) heart rates were most marked in cross-country; the range was from 100 to 219 percent greater than resting heart rates.

Astrand and Saltin (3) included skiing in a study of maximal oxygen uptake and heart rate resulting from participation in various types of physical activity with six males and one female, 22-48 years of age, as subjects, all of whom were considered to be "well trained." The other activities included were: bicycle ergometer, sitting, supine, legs only, and simultaneous arms and legs; treadmill run; swimming; and arm work by cranking. All exercises were intense in nature. For skiing, the subjects skied at speeds high enough to exhaust them within 3-4 minutes. The oxygen consumption for skiing was 4.48 liters, as compared with 4.36 liters for leg cycling and 4.69 liters for running. The range of maximal heart rates achieved for skiing was 188-200 beats per minute. Ranges of heart beats per minute for other activities were 185-192 for running and 185-194 for leg cycling; for swimming, all participants had the same maximal heart rate, 182 beats per minute.

Shephard (38, p. 535) has pointed out that the intensity of exercise in downhill skiing depends on the speed that is attained. He indicated that measurements on champions have shown oxygen consumptions of 3-4 liters/min but the normal recreation skier does not approach this figure; and that substantial isometric loads are thrown upon the legs, so champion downhill skiers often have very strong leg extensor muscles.

Soccer

To study the effects of soccer training and detraining during a soccer season, Fardy (16) established an experimental group of 11 members of the 1966 University of Illinois soccer team and a control group of five undergraduate volunteers who did not engage in vigorous physical activity during the period of the study. The soccer season extended for 10 weeks: initial practice sessions consisted of 20-30 minutes of calisthenics and running, 30-40 minutes of soccer drills, and 1-1½ hours of game situation practice. Once the competitive season began, practices consisted almost entirely of game-type situations.

Each subject was tested on four occasions: pretraining, 5-weeks training, 10-weeks training, and five weeks after training. The evaluative tests were: electromechanical lag (Q to first heart sound), isovolumetric contraction period, and tension period of the left ventricle; peak oxygen intake and peak ventilation; heart rates during a 5-minute standardized submaximal bicycle ergometer ride and all-out ride time. Data were analyzed by a nonparametric statistic, the Friedman two-way analysis of variance by ranks test. The tests that showed significant changes by the experimental group were: increased peak oxygen intake and peak ventilation; shortened isovolumetric contraction phase; longer duration of all-out bicycle ride; and reduction in heart rate for a standard submaximal ergometer ride. The general pattern of change for these measures was an improvement during the first five weeks, no further change during the last five weeks of training, and a decline during the detraining period. No significant changes were made by the control group.

Tennis

From oxygen consumption determinations, Widdowson, Edholm, and McCance (45) assessed the fitness values of various activities and drills employed in training

77 cadets, 18½ to 20 years of age, at a British armed forces center. The values obtained, as expressed in $Cal/m^2/min$ were as follows: 8.0 and 5.0, boxing in the ring and when sparring, respectively; 5.0, fitness training; 5.0 running; 4.8, cycling; 4.0, tennis; 4.0, swimming; and 2.9, golf.

According to Shephard (38, p. 383), experiments on dogs have suggested that forced inactivity may retard the growth of the long bones by as much as 20 to 25 percent. A similar effect can occur in man, which is indicated by the dominant arm being longer than its partner, and this difference is more marked in school-age children than in those aged one to four. Further, indicates Shephard, studies of tennis players have shown substantially greater bone development in the dominant arm.

Volleyball

Wolbers (26) studied the effects of participation in beginning volleyball for 26 weeks, three times a week, on nine adult men, 28-50 years of age. A control group of 10 sedentary men was employed. Compared with the control group, the volleyball participants made significant improvements in resting heart rate, in the obliquity angle of the heartograph in grip, back and leg strengths, and strength per pound of body weight (although a control group also gained appreciably in strength), in the Illinois Agility Run, and in the Larson chin-dip-vertical jump battery. No appreciable changes occurred in systolic amplitude and diastolic pulse wave of the heartograph, in the Schneider Test, or in fat and chest-abdominal girths.

The effects of calisthenics and volleyball on the AAHPER Youth Fitness test items and volleyball skill were studied by Franks and Moore (19). Three classes of tenth grade boys, 22 to 28 each, participated in one of the following physical education classes five days a week for five weeks: combination of calisthenics (10 minutes) and volleyball; all calisthenics; and all volleyball. Volleyball skill was measured by the sum of five serves on a court marked off as described by French and Cooper and by the number of hits during a 30-second wall volley. The calisthenics consisted of strength, agility, and flexibility exercises similar to pregame warmup of a high school football team. The volleyball classes consisted of drills and competition. Both classes including calisthenics in the class activities made significantly greater improvements in situps and pullups than the volleyball-only class; the combination group also did significantly better on the 50-yard dash. The standard score increases on the volleyball wall volley test were: 24 for the volleyball class, 17 for the combination class, and 11 for the calisthenics class.

In a study that antedated Franks and Moore, Hopkins (25) reported on the conditioning effects of participation in volleyball and calisthenics on 30 adult men during a 6-month program, three days weekly; the separate effects of volleyball and calisthenics were not differentiated. Significant improvements were made by the men on the following tests: heartometer brachial pulse wave, obliquity angle, and systolic amplitude; resting pulse rate and Schneider Index; vital capacity residual; and strength per pound of body weight and total proportional strength. Breath holding time and agility run did not improve appreciably, and changes in body fat were not significant.

Four groups of seven to 13 college men each were formed by Garrett, Sabie, and Pangle (20). All groups participated in volleyball instruction for 35 minutes twice a week during a college quarter of 10 weeks. For three to four minutes following the volleyball instruction, each group underwent a different conditioning experience, as follows: Running in place: Subjects ran in place as fast as possible for 10 seconds, followed by a 10-second rest period; this procedure was repeated 10 times.

Rope skipping: The subjects alternated periods of maximal and moderate effort; the pace was set by an instructor. Bench stepping: Using a 17-inch high bench, the subjects stepped up and down at a pace of 30 steps per minute. Continued volleyball participation: These subjects continued with volleyball participation. Cardiovascular fitness was evaluated by the Harvard Step Test. The Brady Test was also given to measure volleyball skill proficiency. The results of this study showed that the step test means of all groups combined increased significantly (F=19.01). The mean gains by experimental groups were: running in place, 15; rope skipping, 13; bench stepping, 8; and continued volleyball instruction, 4. The differences between the groups at the end of the 10 weeks were not significant, so the time spent in conditioning did not detract from volleyball skill improvement.

Double Focus Sports

Seven studies on the effects of various forms of exercise on the improvement of physical fitness components included only two of the focus sports; these studies are summarized in this section. Six of the studies included other activities, such as other sports, dancing, conditioning exercise, etc.

Badminton and Other Focus Sports

Basketball. Armstrong (2) and Cant (7) conducted comparison studies, one year apart, of the heart rate responses of college women when participating in four levels of basketball, three levels of badminton, and three levels of contemporary dance, each ranging from beginning to competitive skill levels. Heart rates were monitored by telemetry during 15-minute activity periods and at other times. When activities were compared in Armstrong's study, the same trend was observed for the mean recovery rise above resting heart rate. The average exercising heart rates for all subjects in each activity were 165 for basketball, 147 for badminton, and 119 for contemporary dance. Thus, based on exercising heart rates, participation in the two sports showed cardiovascular training effects, while this effect for contemporary dance was questionable. Compared with heart rates of all subjects during walking and running, the basketball subjects were comparable to running; the badminton women were similar to run/walk, and the dance participants fell between walk and run/walk. Further, a higher cardiac response was associated with greater interest and skill in the activity.

Cant repeated the study by Armstrong with different college women as subjects. Also, data analyses of the subjects in the two studies were combined for participation in each of the three activities--basketball, badminton, and contemporary dance. Comparable results were produced by both studies.

Tennis. The energy costs of participation in badminton and tennis were determined by Murray (32) with four college women of about average skill in these sports as subjects. Energy cost was determined by the Douglas bag collection of expired air while playing each sport, with analysis by the Scholander analyzer. The mean energy costs were 7.37 Cal/min for tennis and 7.02 cal/min for badminton; the difference between these means was not significant. Tennis and badminton were found to be beneficial means of weight reduction if participation is regular. One pound of body weight could be lost when engaging in tennis for 10.02 hours and in badminton for 10.42 hours.

Volleyball. Wertz (44) telemetered the heart rates of 10 college women during physical education classes. The heart rates were recorded preclass, for 30 minutes during class, and for 10 minutes postclass in the activities of badminton, fencing, fitness and weight control fundamentals, and volleyball. Analysis of variance indicated that 30 minutes of participation in badminton class produced greater stress, as indicated by heart rate, than did 30 minutes of fitness and weight control, fundamentals, or volleyball.

Basketball and Another Focus Sport

Telemetered electrocardiograms were obtained by Griffin (22) from 27 college women participants in field hockey and in basketball during, and for 10 minutes after, contests. The highest heart rates achieved were 220 and 205 beats per minute for hockey and basketball, respectively. The mean heart rates of the players in field hockey were significantly higher than in basketball in five of six instances in which such differences were determined. Roving players in basketball had higher heart rates than did nonroving players. For field hockey, significant differences were not obtained between those playing the forward line and those playing backfield positions. The investigator concluded that the playing of field hockey is more strenuous, in terms of resultant heart rates of the players, than is the playing of basketball. Also, the heart rates of field hockey players remained elevated at a higher level during period of recovery following contests than did the heart rates of basketball participants.

Tennis and Another Focus Sport

Archery. Edholm, Fletcher, Widdowson, and McCance (14) determined the oxygen consumption values of various activities and drills employed in training 97 cadets, 18½ to 20 years of age at a British armed forces center. These values expressed as Cal/min were as follows: 11.67, running in uniform at 7.5 miles per hour; 10.18, playing squash; 7.92, cycling; 7.13, tennis; and 5.24, archery.

Bowling. Heart rate comparisons of college women while participating in tennis, bowling, fencing, and golf classes twice weekly for 10 weeks were made by Laing (31); the number of subjects in each sport was five. Electrocardiographic recordings were taken by telemetry on each subject twice during the 10-week period. Each time the heart rate was recorded for five seconds at the end of every minute for 20 minutes. The mean resting heart rates per minute for the four activity groups ranged from 73.8 for golf and fencing to 77.6 for tennis; the differences between the means were not significant. The mean heart rates per minute during class instruction were: 104.8, bowling; 115.8, fencing; 119.6, golf; 129.9, tennis. The mean increases over resting heart rates were: 30.1, bowling; 42.0, fencing; 45.8, golf; and 52.3, tennis. The differences between heart rate means during participation in the four sports were not significant as determined by analysis of variance. By inspection, it would be anticipated that some mean differences would be significant, especially between bowling (104.8) and tennis (129.9). The investigator suggested that the lack of significance may be due to large standard deviations for the groups, indicating wide variance in individual heart rate responses. The investigator indicated that none of the activities produced heart rates sufficiently high to result in cardiovascular conditioning. It should be stressed that the subjects were beginners in the respective sports; thus, the results of this study should not be assumed for more skilled participants who logically may be more active.

Volleyball. Landiss (72) studied the effects on college men of a semester's participation in eight physical education class activities upon motor ability and motor fitness test batteries. In addition to tennis and volleyball, the class activities were boxing, conditioning, swimming, tumbling-gymnastics, weight training, and wrestling. The tests utilized for evaluation were the Larson Test of Motor Ability and a modification of the Army Air Forces Physical Fitness Test (World War II battery). These tests consist mostly of muscular endurance, agility, and power items, although the AAF test contains a 300-yard run. Participants in all class activities except swimming improved significantly on the motor fitness battery; the tennis and volleyball groups produced results comparable to the weight training, wrestling, and boxing groups. For the motor ability battery, participants in all class activities except swimming and boxing improved significantly. The strongest overall achievements on the two test batteries were made by the wrestling, tumbling-gymnastics, and conditioning participants.

Three or More Focus Sports

Six studies on the physical fitness benefits from sports participation were conducted in which between three and six focus sports were included. Four of these studies were with college women as subjects and two were with male subjects.

College Women

Two college women were tested by Skubic and Hodgkins (40) to determine the relative strenuousness of participation in archery, badminton, basketball, bowling, golf, hockey, softball, tennis, and volleyball. The subject's heartbeats were telemetered during participation in each sport and estimates of their lung ventilation and oxygen uptake for each activity were determined under laboratory conditions. The rating of activities was as follows: heavy activity, roving player in basketball and center halfback in hockey; moderate activity, nonroving positions of forward and guard in basketball, badminton, tennis, softball pitcher, and volleyball; light activity, archery, golf, and bowling. Heart rates ranged from a mean of 85 beats per minute in bowling to 185 beats per minute for the roving player in basketball. The energy expenditure of the roving player in basketball was similar to that of the center halfback in hockey; these two positions required greater oxygen uptake than the positions tested in all other sports.

In a second study by Skubic and Hodgkins (39), energy expenditures while running on a treadmill were determined for two college women of comparable age, height, weight, cardiovascular efficiency, and skill in sports. Ventilation, oxygen consumption, and caloric expenditure were determined when heart rates reached various levels during the treadmill run. The subjects also participated in the playing of five individual-type sports: archery, badminton, bowling, golf, and tennis. Heart rates were telemetered throughout the playing of each sport. Regression coefficients for each subject were found showing the relationships between heart rate and ventilation, heart rate and kilocalories, and heart rate and oxygen consumption for exercise on the treadmill. From these data, the energy cost of participation in each of the five sports was estimated from the known heart rates. The results indicated that badminton and tennis were significantly more strenuous than golf, bowling, and archery. According to then available energy cost classifications, badminton and tennis were rated as moderate activities and golf, bowling, and archery were rated as mild activities.

Smalley and Smalley (41) studied endurance and arm and shoulder girdle strength changes in college women participating for eight weeks in classes in archery, badminton, basketball, dance fundamentals, fencing, field hockey, folk dancing, tennis, volleyball, and swimming. The test of endurance was the number of squat thrusts performed while maintaining a cadence of a complete squat thrust each four seconds. Arm and shoulder girdle strength was tested as pushing and pulling strengths combined with a manuometer equipped with attachments for this purpose. A nonactivity, or control, group was also tested. Women in all activities but archery, basketball, and tennis made significant improvements on endurance scores (.05 level); the greatest mean gains were made by the swimmers, fencers, and folk dancers. For the strength measure, all but the hockey, folk dance, swimming, and fencing participants made significant gains; the greatest improvements were made by those participating in volleyball, dance fundamentals, archery, and badminton. The control group remained essentially the same on both the endurance and strength measures.

Men

Telemetered heart rate records were obtained by Kozar and Hunsicker (28) from 23 adult men during participation in six sports: badminton, bowling, handball, paddleball, tennis, and volleyball. The subjects were selected from University of Michigan students and faculty on the bases of good physical condition and superior sports skills. Each heart rate was recorded for 15 seconds every two minutes for 30 minutes. The mean heart rates (given in parenthesis) for handball (166), paddleball (164), tennis (159), and badminton (150) did not differ significantly from each other, but were significantly greater than for volleyball (136) and bowling (99). The mean heart rate in volleyball was significantly greater than in bowling. Considerable variability was found in heart rates during the various contests. The investigators observed that this was not only due to individual differences among the contestants but also to adjustments made during high work intensities and between games or points. None of the competitive sports was a steady-state activity; each required everchanging cardiovascular responses to varied demands and mental involvements during the contests.

Howell and associates (26) evaluated the effects of five intercollegiate athletic activities upon treadmill performance as measured by the Balke-Ware test; measures of exercising heart rate, oxygen consumption, carbon dioxide production, respiratory quotient, and inspired volume were also obtained. The varsity athletic activities were basketball, volleyball, ice hockey, swimming, and wrestling. The basketball, ice hockey, and swimming athletes significantly increased their performances on the treadmill test and decreased their exercising heart rate. No significant changes occurred for the volleyball athletes and the wrestlers.

Boys' Summer Youth Fitness Schools

Rathermel, Pollock, and Cureton (36) reported changes in scores on the items composing the AAHPER Youth Fitness Test from eight weeks of participation in the University of Illinois Sports-Fitness Summer Day School. The subjects were 65 boys between the ages of 7 and 13 inclusive; a control group of 22 boys of comparable age, height, and weight was also tested. The activity program lasted three hours each afternoon, Monday through Thursday, and consisted of 30 minutes in each of the following: aquatics, gymnastics, track and field, conditioning activities, and endurance running. The fitness effects from sports participation and the fitness contributions of the conditioning activities were not differentiated; thus, the results apply to the total

program. The test items showing significant gains at and above the .05 level were: pullups, situps, standing broad jump, and 600-yard run. These items purported to evaluate muscular strength and endurance, power, and circulatory-respiratory endurance. The items that did not show significant changes were softball distance throw, shuttle run, and 50-yard dash. The control group did not change appreciably on any test.

Faulkner, Greey, and Hunsicker (17) telemetered the pulse rate of boys ranging from seven to 12 years of age attending the University of Michigan Summer Youth Fitness School. Three- to 4-second readings were taken every five minutes of a swimming, gymnastics, or sports skills activity class, each period of which lasted 35 minutes per day. Forty-two subjects were selected at random, 14 boys from each of the three activities. Five radio electrocardiograms were recorded for each subject, giving 210 recordings. The mean heart rate of the boys participating in sports skills was significantly higher than those in swimming and gymnastics. However, the individual variances of the subjects were extreme for all these activities. The ranges in mean heart rate beats per minute were: 122-180 for sports, 97-166 for gymnastics, and 88-166 for swimming. The investigators concluded that the opportunity for vigorous activity does not necessarily imply that all participants are going to give maximal efforts.

Summarization and Implications

1. In this issue of the *Physical Fitness Research Digest*, additional activities that may be utilized to improve physical fitness components, especially muscular strength, muscular endurance, and circulatory-respiratory endurance, are considered. The activities consisted primarily of the following 12 sports: archery, badminton, basketball, bowling, handball, field hockey, ice hockey, paddleball, skiing, soccer, tennis, and volleyball. These sports are designated herein as focus sports, to differentiate them from others included in some of the studies reported. Earlier *Digests* were devoted to other activities utilized for this purpose: "Jogging," January 1977; "Swimming and Bicycling," July 1977; and "Rope Skipping-Dancing-Walking and Golf-Pack Carrying," October 1977.

2. Most people have some "notion" concerning the physical vigor resulting from participating in the sports listed. Thus, generally, archery and bowling are thought to be mild, providing little physiological stimulation, while basketball and soccer are considered to be vigorous in nature, especially taxing the circulatory-respiratory system. The results of studies bear out these views, thus, perhaps, "proving the obvious." However, documentation of this situation insofar as available studies permit is desirable; it would also be helpful to know if the milder sports can make any contribution at all toward the improvement of physical fitness components.

3. As contrasted with experiments utilizing weight training, jogging, and other activities considered in earlier *Digests* on the improvement of physical fitness components, the use of sports for this purpose presents several problems. These problems include: (a) The effort made, and thus the energy expended, in a sports situation is hard to quantify; participation takes place, of course, but the intensity of the participation is not known. (b) Intensity of participation will vary from individual to individual and from time to time depending upon the participant's level of skill and upon the opponent's level as well. (c) Intensity will normally differ in such court sports as tennis and badminton depending upon whether singles or doubles matches are played. (d) Evaluations of sports fitness benefits from class situations do not differentiate between actual play and time spent in explanations, practice of

fundamentals of the sport, and drills. (e) Comparison of the results of sports participation after a lapse of years may be invalidated to some degree if significant rule changes have occurred and new techniques of play have been introduced.

4. The amount of research on the improvement of physical fitness components through participation in sports is very sparse for some sports, while for others the amount is considerably greater. From the 46 studies reviewed in this account, 68 evaluations of focus sports were made, distributed as follows: 19, basketball; 12 each, badminton, tennis, volleyball; 6, archery; 5 each, bowling, handball, field hockey, skiing; 3 each, paddleball, soccer; 2, ice hockey.

5. Three comprehensive evaluations of contributions from participation in various activities in the improvement of physical fitness components were made; one evaluation was based on the opinions of physicians and the other two were parts of exercise systems proposed in Cooper's Aerobic Point System and in Kuntzleman's Fitness Finders. A melding of these evaluations would place participation in the focus sports in the following categories:

Most Vigorous:	cross-country skiing; and vigorous basketball and singles in handball and tennis.
Moderate:	moderate basketball, handball, soccer, and tennis and vigorous volleyball.
Mild:	archery and bowling.

6. An attempt was made to analyze the physical fitness benefits realized from participation in each of the 12 focus sports; these analyses follow, presented by sports in alphabetical order. Differences between means and gains reported are significant unless otherwise stated.

Archery: Improvement in arm and shoulder girdle pulling, but not pushing, strength; no endurance gains, as based on low maximum heart rate and energy cost and upon length of time squat thrusts can be continued at a set cadence.

Badminton: Mean maximum heart rates achieved between 148 and 165 beats per minute, which is comparable to walk-run; energy cost around 7.02 Cal/min, not significantly different from tennis; increases in push plus pull strength and in number of squat thrusts performed at a set cadence; no gains in muscular endurance.

Basketball: Increase in aerobic capacity by as much as 83% for a men's college varsity team; maximum heart rates between 185 and 212 beats per minute achieved and expenditures of 642 and 502 calories during playing of collegiate games by college women; blood lactate production reduced; improvement on several strength tests; decreases in several skinfolds and girths by women.

Bowling: Maximum heart rates of 85, 99, and 105 beats per minute reported.

Handball: Improved heartometer brachial pulse wave measured and Schneider cardiovascular test; increased chest expansion; mean maximum heart rate of 166 beats per minute reported for college men; no improvements on respiratory, strength, and agility tests.

Hockey, Field: Studies of college women only: highest maximum heart rate achieved, 220 beats per minute; mean maximum heart rate significantly higher than for

basketball; increase in number of squat thrusts performed at a set cadence; playing center halfback rated as heavy activity and playing other positions rated as moderate activity; no gains in push-plus-pull strength of arm and shoulder girdle muscles.

Hockey, Ice: College varsity team increased significantly on the Balke-Ware treadmill test.

Paddleball: Peak heart rate of 159 beats per minute and mean maximum heart rate of 143 beats per minute for adult men (higher than for calisthenics and lower than for running) in one study; mean maximum heart rate of 164 beats per minute reported in a study of college men.

Skiing: Mean maximum heart rate ranges of college skiers in competition, 187-200 for cross country, 158-167 for downhill, and 115-166 for jump, expressed in beats per minute; downhill ski champions consume 3-4 liters of oxygen per minute; mean oxygen consumption of 4.48 liters and maximum heart rates of 188-200 beats per minute for 3-4 minutes of all-out skiing by well-trained skiers.

Soccer: University soccer team during a competitive season increased peak oxygen intake and peak ventilation, shortened isovolumetric phase of the heart contraction, lengthened duration of standard all-out bicycle ergometer ride, and reduced heart rate for standard submaximal ergometer ride.

Tennis: Energy costs of 5.13 and 7.37 Cal/min reported; mean maximum heart rates obtained, 130 and 159 beats per minute for college women and men, respectively; bone growth increased in exercising arm; nonsignificant changes for number of squat thrusts performed at a set cadence, Schneider cardiovascular test, and push-plus-pull arm and shoulder girdle strength.

Volleyball: For adult men beginners, improvements in obliquity angle of heartograph, resting heart rate, various strength tests, Larson Test of Motor Ability, and Illinois Agility Run; for college men, mean maximum heart rate of 136 and improvements on the Larson test and modified form of AAF Physical Fitness Test (World War II); increased number of squat thrusts performed at set cadence; nonsignificant changes in AAHPER Youth Fitness Test items, Balke-Ware treadmill test, and push-plus-pull strength of arms and shoulder girdle muscles.

7. Participation of boys in sports-fitness summer day schools at the Universities of Illinois and Michigan produced desirable changes on physical and motor fitness tests. In the Michigan program, the mean heart rate ranges per minute were 122-180 for sports, 97-166 for gymnastics, and 88-166 for swimming.

8. As has been consistently noted in various issues of the *Physical Fitness Research Digest*, proper principles of exercise should be observed by participants in activities intended to improve physical fitness components. Such principles were presented in the October 1976 issue, "Physical Fitness Practices and Programs for Elementary and Secondary Schools." Especial attention should be paid to the following: (a) Exercise should be adapted to the individual's exercise tolerance. (b) Reasonable "overloading" should be applied to induce higher levels of performance. (c) The exercise should be progressive. Sedentary individuals should approach participation in vigorous sports with some caution, since the competitive aspect present is conducive to the violation of proper principles of exercise.

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